1-Assembly line balancing (Product)

* Definitions:
- Work element: It the non-divisable part at final work breakdown
- Elemental time: It is the time of producing an element
- Work station time: It is the time at which element presents in the work station specified
- Total work content: It is the total of elemental times
- cycle time: It is time stations to work

* Laws:
- Production rate $= \frac{1}{C}$ → cycle time
- $C = \frac{T}{N}$ → Total time for production (Total work content); → No. of stations
- $n_{min} = \frac{\sum_{i=1}^{n} t_i}{C}$ → No. of products; → Min no. of stations
- $\bar{C} = \frac{\sum_{i=1}^{n} t}{n}$ → Actual no. of stations $< C$; → Actual cycle time
- Balancing loss % $= \frac{C - \bar{C}}{C} \times 100\% = \frac{nC - \sum_{i=1}^{n} t}{nC} = 10.20\%$
- Max. production rate $= \frac{1}{\text{time of workstation of min. time}}$

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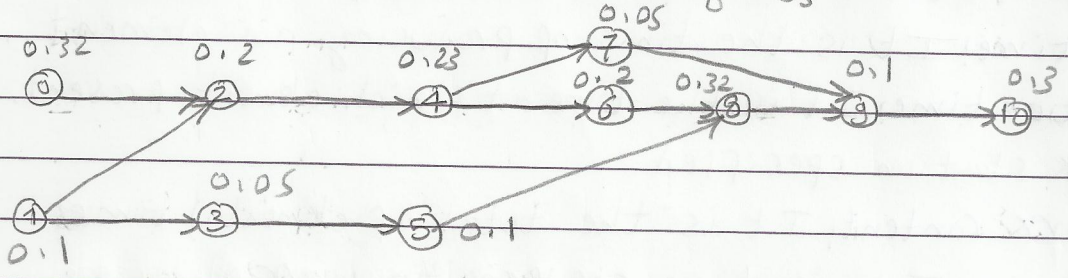
*Example:

It is required to balance the line, knowing that the cycle time is 0.55 hr (An O/P of 1.82 per hr). Determine the no. of stations & the balancing loss



* Using ranked positional weight

$(PW_i) = \sum_{i=1}^{n} t_i$; (n) all activities depending on (i) and itself

$PW_0 = 0.32+0.2+0.23+0.05+0.2+0.32+0.1+0.3 = 1.72$ hr

$PW_1 = PW_0 + 0.32+0.05+0.1+0.1 = 1.65$ hr

$PW_2 = PW_0 - 0.32 = 1.4$ hr

$PW_3 = 0.05+0.1+0.32+0.1+0.3 = 0.87$ hr

$PW_4 = PW_2 - 0.2 = 1.2$ hr

$PW_5 = PW_3 - 0.05 = 0.82$ hr

$PW_6 = 0.2+0.32+0.1+0.3 = 0.92$ hr

$PW_7 = 0.05+0.1+0.3 = 0.45$ hr

$PW_8 = 0.32+0.1+0.3 = 0.72$ hr

$PW_9 = 0.1+0.3 = 0.4$ hr

$PW_{10} = 0.3$ hr

	(1)	(2)	(3)	(6)	(4)	(7)	(5)	(9)	(8)	(10)	(11)	
Element no.	0	1	2	3	4	5	6	7	8	9	10	Total
Elemental time	0.32	0.1	0.2	0.05	0.23	0.1	0.2	0.05	0.32	0.1	0.3	1.97
PW	1.72	1.65	1.4	0.87	1.2	0.82	0.92	0.45	0.72	0.4	0.3	
Immediate Predessors	—	—	0,1	1	2	3	4	4	5,6	8	9	

$$N_{min} = \frac{\sum_{i=1}^{10} t_i}{C} = \frac{1.97}{0.55} = 3.58 \rightarrow 4$$

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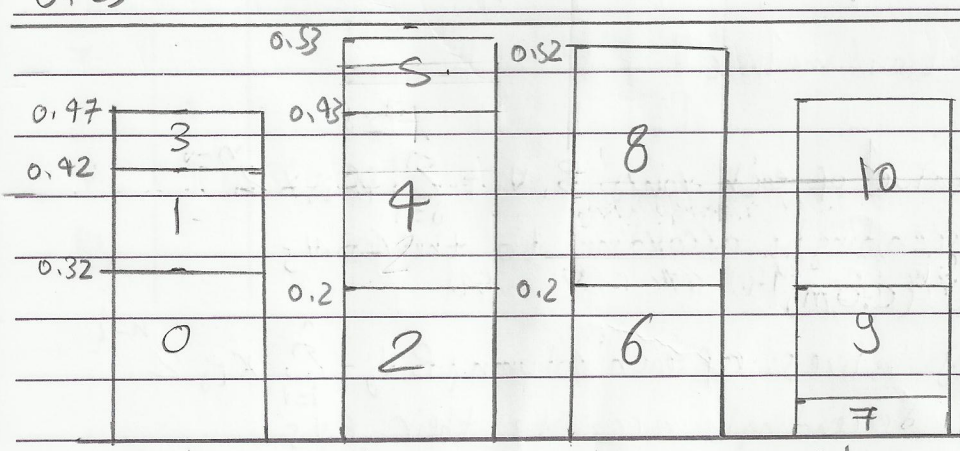
Work station	Element	PW	Immediate predessor	Elemental time (ti)	Cummulative station time (C)	Unsigned station time (C-x)
1	0	1.72	—	0.32	0.32	0.23
	1	1.65	—	0.1	0.42	0.13
	3	0.87	1	0.05	0.47	0.08
2	2	1.4	0,1	0.2	0.2	0.35
	4	1.2	2	0.23	0.43	0.12
	5	0.82	3	0.1	0.53	0.02
(3)	6	0.92	4	0.2	0.2	0.32
	8	0.72	5,6	0.32	0.52	0.03
4	7	0.45	4	0.05	0.05	0.5
	9	0.4	8	0.1	0.15	0.4
	10	0.3	9	0.3	0.45	0.1

Balancing of work stations

0.55



$$\text{Balancing loss} = \frac{nC - \sum_{i=1}^{10} t}{nC} = 1 - \frac{1.97}{4 \times 0.55} \times 100 = 10.45\%$$

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2- Group technology (Cellular M.S.)

*- Component - operation matrix:

Component	Operation (1)	Operation (2)	— — —	Operation (n)
1	x_1			
2	x_2			
⋮	⋮			
n	x_n			z_n

↑ Component no. ↑ M/C no.

- Ranked order cluster (R.O.C.): Max. no. of M/Cs in one cell

M/C \ Comp.	1 2 — — — n	Binary value
1	Fill with (1) in its place ⇒ Repeated not filled twice	
2		
3		
⋮		
⋮		
⋮		
M ↑		

Biggest no. in component - operation matrix

1- Calculate binary values of each row: $B.V_i = \sum_{j=1}^{n} x_{ij} \times 2^{n-j}$

2- Arrange rows descendingly according to their B.Vs

3- Construct a new (C.O.M)

4- Calculate binary values of each column: $B.V_j = \sum_{i=1}^{n} x_{ij} 2^{n-i}$

5- Arrage columns descendingly acc. to their B.Vs

6- Repeat the previous steps till both rows & columns are arranged descendingly together

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* Example:

Component	Operation (1)	Operation (2)	Operation (3)	Operation (4)
1	2	9	8	
2	2	6	8	9
3	9	8	4	8
4	3	5		
5	1	5		
6	7	4	7	
7	1	5		
8	4	7	(10)	
9	5	3	1	

- R.O.C.

	(256)	(128)	(64)	(32)	(16)	(8)	(4)	(2)	(1)	
M/C \ Comp.	1	2	3	4	5	6	7	8	9	B.V.
1					1		1		1	21
2	1	1	1							384
3				1					1	33
4			1			1		1		74
5				1	1		1		1	53
6		1								128
7						1		1		10
8	1	1	1							448
9	1	1	1							448
10								1		2

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M/C \ Comp.	1	2	3	4	5	6	7	8	9	B.V.
(128) 8	1	1	1							448
(256) 9	1	1	1							448
(128) 2	1	1								384
(64) 6		1								128
(32) 4			1			1		1		74
(16) 5				1	1		1		1	53
(8) 3				1					1	33
(4) 1					1		1		1	21
(2) 7						1		1		10
(1) 10								1		2
B.V.	896	960	800	24	20	34	20	35	28	

	(256)	(128)	(64)	(32)	(16)	(8)	(4)	(2)	(1)	
M/C \ Comp.	2	1	3	8	6	4	9	5	7	B.V.
8	1	1	1						1	448
9	1	1	1						1	448
2	1	1								384
6	1									256
4			1	1	1					112
5						1	1	1	1	15
3						1	1	1	1	12
1							1	1	1	7
7				1	1					48
10				1						32
B.V.	960	896	800	38	34	28	24	20	20	

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Comp. / M/C	2	1	3	8	6	4	9	5	7	B.V.
(512) 8	1	1	1							448
(256) 9	1	1	1							448
(128) 2	1	1								384
(64) 6	1									256
(32) 4			1	1	1					112
(16) 7				1	1					48
(8) 10				1						32
(4) 5						1	1	1	1	15
(2) 3						1	1			12
(1) 1							1	1	1	7
B.V.	960	896	800	56	48	6	7	5	5	

(256) (128) (64) (32) (16) (8) (4) (2) (1)

Comp. / M/C	2	1	3	8	6	9	4	5	7	B.V.
8	1	1	1							448
9	1	1	1							448
2	1	1								384
6	1									256
4			1	1	1					112
7				1	1					48
10				1						32
5						1	1	1	1	15
3						1	1			12
1						1		1	1	11
B.V.	960	896	800	56	48	6	7	5	5	

For component (3) semi operations are done in both cells or one other m/c is used

Cell (1)
M/C 8 9 2 6 → Comp. 2 1 3

Cell (2)
M/C 4 7 10 → Comp. 8 6

Cell (3)
M/C 5 3 1 → Comp. 9 4 5 7

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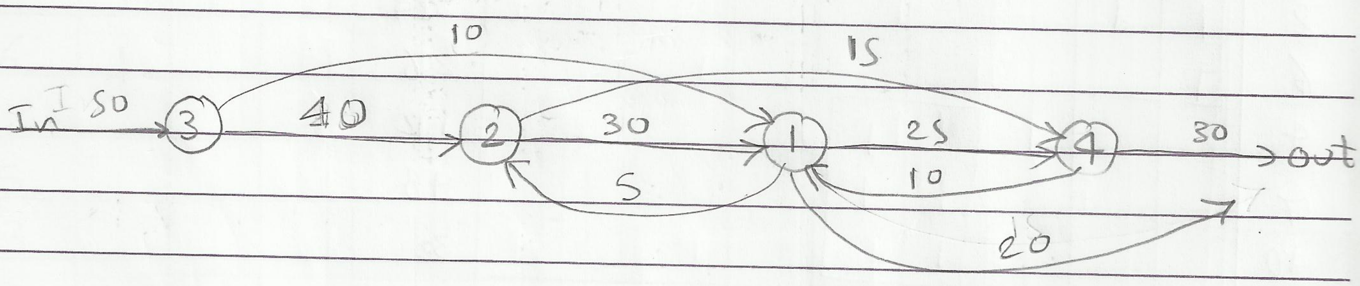
* Hollier's Alogorism: Min. distance from/to

1- Develop From/To chart from part routing data
2- Determine F & T sums
3- Assign m/cs to cells base on min F or T
4- Draw routing diagram & check to add some parts

Example:

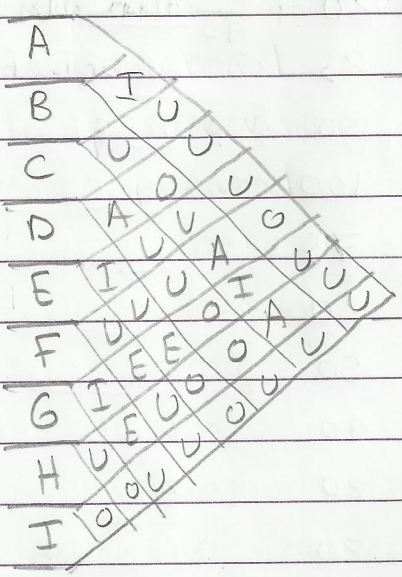
From \ To	1	2	3	4	Sum		
1	0	5	0	25	30	30	25
2	30	0	0	15	45	45	—
3	10	40	0	0	50	—	
4	10	0	0	0	10	10	10
Sum	50	45	(0)	40			
	40	(5)	—	40			
	10	—	—	25			

(3) → (2) → (1) or (4)

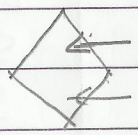


3- Facility planning layout (process)

* Activity relationship chart:



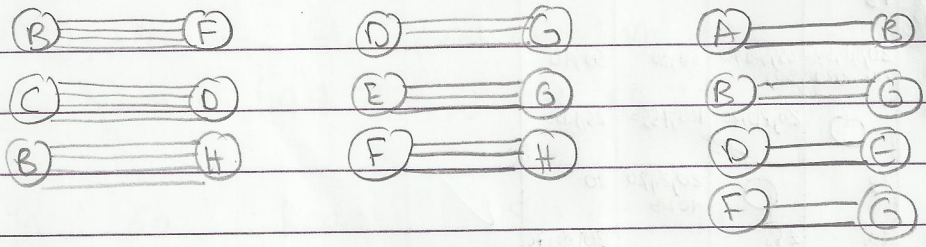
≡ (A) Absolutly necessary
≡ (E) Especially necessary
= (I) Important
_ (O) Ordinary
(U) Unimportant
m (X) Undesired



→ Flow of material
→ Ease of supervision
→ Common personnel

* Activity relationship diagram:

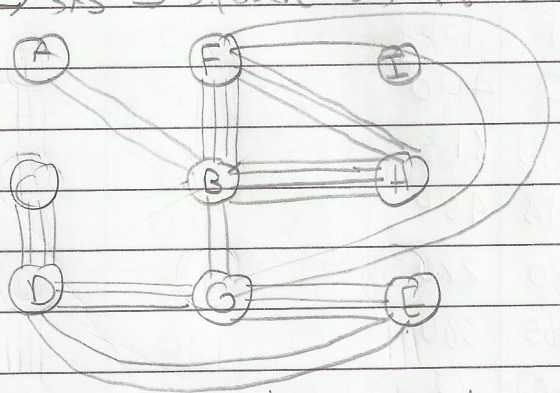
A ≡ E ≡ I = X _



High effective → low quantity
Low effective → High quantity

⇒ (O & U) avent considered

9 ⇒ 3×3 ⇒ square as it is possible



Activity relationship diagram

A	F	I
C	B	H
D	G	E

Block lay out

Repeat according to no. of repetitions

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* From-To chart from sequence matrix:

Product	Sequence	Monthly Production volume	Bulk factor	No of unit loads
1	A B C D E F (20 20 20 20 20)	800	40	$20 = \frac{800}{40}$
2	A B D E D C F	1000	40	25
3	A B E F	600	20	30
4	A B C E B C F	2000	20	100
5	A C E F	1500	20	75
6	A B C D E F	400	20	20
7	A B C B D B E B F	2500	50	50
8	A B D E C B F	2000	50	40
9	A B C D F	800	40	20
10	A B D E F	1000	5	20

Fill the units

* Flow matrix:

From \ To	A	B	C	D	E	F	Total
A	0	20,25,30 100,20,50 40,20,20	75				
B		0	20,100,100 20,50,20	25,50,40 20,	30,50	50,40	
C		50,40	0	20,20,20	100,75	25,100	
D		50,	25	0	20,25,20 40,20	20	
E		100,50	40,	25,	0	20,30,75 20,20	
F						0	
Total							

From \ To	A	B	C	D	E	F	Total
A	0	325	75	0	0	0	400
B	0	0	310	135	80	90	615
C	0	90	0	60	175	125	450
D	0	50	25	0	125	20	220
E	0	150	40	25	0	165	380
F	0	0	0	0	0	0	0
Total	0	615	450	220	380	400	2065

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4- Total material handling Cost (TMHC)

Example:

Product	Prod^n Vol.	Bulk factor	Sequence	No. of unit loads
1	8000	200	11 22 44 66 SS 88	40
2	4000	100	11 33 SS 77 66 88	40
3	5000	100	11 44 33 66 77 33 88	50
4	600	20	11 22 33 SS 22 88	30
5	800	50	11 SS 44 22 66 88	16
6	5000	50	11 44 SS 66 77 88	/
7	4000	100	11 SS 66 33 44 66 88	40
8	1000	50	11 22 33 66 SS 66 88	20

For product 6, after completing its process at (44), it is split to 2 paths:

1- 60% of the production volume continues processing through the given sequence with a bulk factor of 50

2: 40% of the production volume continues through the following sequence: (44 77 33 44 SS 77 88) with a bulk factor of 20

*	6a	3000	50	11 44 SS 66 77 88	60
	6b	2000	20	11 44 77 33 44 SS 77 88	100

1- Flow matrix

From \ To	11	22	33	44	SS	66	77	88	Total
11	0	90	40	210	56	0	0	0	396
22	0	0	50	40	0	16	0	0	106
33	0	0	0	140	70	50	0	50	310
44	0	16	50	0	60	80	0	0	206
SS	0	30	0	16	0	130	140	0	316
66	0	0	40	0	60	0	110	116	326
77	0	0	150	0	0	40	0	160	350
88	0	0	0	0	0	0	0	0	0
Total	0	136	330	406	246	316	250	326	2010

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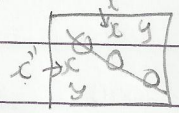
2- Assumed layout;

11	55	22	77
33	88	66	44

$TMHC = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij}\, d[a(i), a(j)]\, C_{ij}$; For non-symmetric matrix

$TMHC = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij}\, d[a(i), a(j)]\, C_{ij}$; For symmetric matrix



$\frac{x' + x''}{2} = x$

3- Cost matrix;

- Not stated → (1)

From \ To	11	22	33	44	55	66	77	88
11	0	1	1	1	1	1	1	1
22	1	0	1	1	1	1	1	1
33	1	1	0	1	1	1	1	1
44	1	1	1	0	1	1	1	1
55	1	1	1	1	0	1	1	1
66	1	1	1	1	1	0	1	1
77	1	1	1	1	1	1	0	1
88	1	1	1	1	1	1	1	0

4- Distance matrix;

- Distance
  - → Linear (Line from point to point)
  - → Rectilinear (x, y) ⇒ used
  - → Actual

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From \ To	11	22	33	44	SS	66	77	88
11	0	2	1	4	1	3	3	2
22	2	0	3	2	1	1	1	2
33	1	3	0	3	2	1	1	2
44	4	2	3	0	3	1	1	2
SS	1	1	2	3	0	2	1	2
66	3	1	1	1	2	0	2	1
77	3	1	1	1	1	2	0	3
88	2	2	2	2	2	1	3	0

4- MHTC matrix:

From TO	11	22	33	44	SS	66	77	88	Total
11	0	180	40	840	56	0	0	0	1116
22	0	0	150	80	0	16	0	0	246
33	0	0	0	420	140	50	0	50	660
44	0	32	150	0	180	80	0	0	442
SS	0	30	0	48	0	260	140	0	478
66	0	0	90	0	120	0	220	116	496
77	0	0	150	0	0	80	0	320	550
88	0	0	0	0	0	0	0	0	0
Total	0	242	490	1388	498	486	360	486	

MHTC = 3988 + 3948 = 7936 unit of cost

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